THE CASE FOR INVESTING IN CLIMATE RESILIENCE

APPLICATION OF A DYNAMIC DECISION TOOL

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ABSTRACT

Extreme weather events have increased in frequency and severity as a result of climate change. In the past decade, Australia and New Zealand have experienced the impact of significant climate-related disasters highlighting the need for action and investment in climate resilience. The increased risk these events pose has driven the insurance market to rethink the cover offered to businesses, leading to significantly higher premiums or exclusion of coverage for events of this nature.

In response, asset-intensive organisations are challenged by making timely investments in climate resilience to avoid major impacts, including continuity of service to customers and protection of critical assets. When building resilience to climate-driven risks, the benefits of a solution are assessed by avoiding the full-scale impact of the risk event. Many organisations rely on traditional cost benefit analysis (CBA) analytical methods to evaluate their options. However, a traditional CBA method can undervalue or misrepresent climate resilient investments due to its approach of calculating the benefit, the value of avoided losses or damages. The variability and complexity of these ever-dynamic climate risks creates greater uncertainty in the CBA model and the underlying assumptions. In addition, the fear of over investing and creating a 'white elephant', or stranded asset, that ultimately does not deliver value can result in decision-makers seeking more certainty to justify the value of climate resilient investments leading to decision paralysis and inaction.

To address this challenge, we have developed a dynamic decision tool which utilises the framework of a CBA and can integrate emerging methods including scenario analysis and dynamic sensitivity analysis to assess the value of climate resilient investment options. We present a case study assessing climate resilient options to prepare for the impact of a flood event for a major water utility in Australia. To assess the resilient investment options, we compared the cost of each option against the consequences avoided if a flood event of different magnitudes were to occur, including the consequence of inaction.

The outcomes of the analysis were presented and communicated to decision-makers through an interactive web-based dynamic decision tool, allowing them to understand the comparative performance of options across a range of possible climate scenarios. Each variable can be tested to understand its sensitivity. In addition, a Monte Carlo simulation can indicate the variance and probabilistic outcomes based on the underlying assumptions. Through this analysis decision-makers can understand the value and trade-offs when considering resilient investments to climate change-driven risks, leading to informed decision-making.

KEYWORDS

Climate Change, Risk, Resilience, Adaptation, Investment, CBA, Flood, Decision Tool

PRESENTER PROFILE

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1. INTRODUCTION

Our world is becoming increasingly vulnerable to natural disasters and extreme weather events driven by climate change. Despite this reality, the recent IPCC report suggests the pace and scale of climate action is insufficient to tackle these climate change impacts (IPCC, 2023). As the frequency and severity of these events escalate, the inability for our communities to fully recover further compounds the impact of a subsequent event. Therefore, investing in climate resilience to reduce risk exposure and protect the continuity of our critical services is necessary to avoid the consequences of these events.

The Global Risk Report (World Economic Forum, 2023), which reflects the views of senior leaders in industry around the world, highlighted the following top three risks as causing the most concern between now and 2030.

1. Failure to mitigate climate change,
2. Failure of climate-change adaptation, and
3. Natural disaster and extreme weather events

These insights are unsurprising with over half of the survey participants anticipating progressive tipping points and persistent crises leading to catastrophic outcomes over this period.

Historically, these types of natural disaster and extreme weather events have been considered 'tail risks' or rare events. These are defined as low likelihood, but high consequence risks that statistically occurred multiple standard deviations from the mean. However, due to the impacts of climate change, the frequency and severity of these disasters are increasing. Traditionally, organisations have relied on insurance levers as a last form of protection from natural disaster impacts. Insurance can only provide compensation to aid the recovery and does not prevent damage. In addition, as the frequency and severity of these events worsen, insurers are increasingly refusing cover; only providing partial cover or charging large premiums to insure against these climate change-driven risks. Within this dynamic financial and climate landscape, businesses need to adapt to find long-term economically viable solutions that focus on building resilience to avoid impacts of climate change-related risks.

2. THE CHALLENGE WITH MAKING THE CASE FOR INVESTMENT

As the global risk report states (World Economic Forum, 2023), there is broad agreement among surveyed leaders for the need to adapt to climate-related risks.

However, the intersection between the science, the modelling, and the commitment to action creates complexity in communicating and addressing the challenges to decision-makers, many of whom may not have a detailed understanding of climate change-related risks (Orlove, et al., 2020). These extreme events do not manifest in a consistent way and there is inherent uncertainty in the scale, location, severity, frequency, and timing of these events. Adaptation options can be costly upfront and due to the level of uncertainty, there are fears that certain decisions could result in unintended consequences. One such example is investments that are a significant financial commitment but deliver little value due to their effectiveness. These investments are termed white elephants or stranded assets. A concern for asset-intensive organisations is how to make the case for investment, given the multiple competing priorities and demands. Decision-makers often seek a clear understanding of trade-offs between options which has been traditionally evaluated through a cost benefit analysis (CBA). However, CBA can have several limitations due to the confidence in the underlying assumptions leading to a lack of acceptance in outcome.

2.1 TRADITIONAL CBA APPROACH

The outputs of a CBA can be expressed as a Net Present Value (NPV) or a Benefits Cost Ratio (BCR) which presents the analysis as a single metric. A positive NPV indicates that the projected economic benefit, discounted for present value, is expected to exceed the anticipated costs. A BCR above 1 indicates a net economic gain as the value of the benefits are greater than the costs. When evaluating climate change-driven risk events, calculating the benefits involves multiplying the probability of a climate change-driven event occurring by the avoided negative consequences. There are limitations with this approach resulting in the misrepresentation of outcomes that stem from how low likelihood, high consequence events are calculated.

Firstly, CBA typically does not account for broader societal, environmental, or other intangible costs and benefits. These limitations hinder decision-makers from considering the total costs and benefits of avoiding the consequence of an extreme event, the extent to which can be several orders of magnitude greater for communities and stakeholders than asset owners.

Secondly, the dynamic and sometimes unprecedented nature of climate-related impacts creates low confidence in the certainty of evaluated benefits and costs within a CBA. Assumptions are made for the variables and input data sets that could significantly impact the outputs due to poor data quality and availability. A typical CBA will model a deterministic outcome with no randomness or variation in the ways that inputs get delivered as outputs.

Thirdly, typical CBA models may not consider multiple or concurrent climate events occurring and the change in frequency and severity of an event over time. For example, a 1:100-year event has a 1% probability of occurring in the current year and could occur multiple times over an assessment period. In addition, the probability of the event is likely to increase over time, therefore the same scale of event could become a 1:50-year event in the near future.

Finally, these types of adaptation measures create a trade-off between short-term cost and long-term benefit. Monetary estimates of costs are more accurate than the estimation method of benefits due to the long-term time horizon further creating uncertainty in the estimate value.

2.2 EMERGING APPROACHES

Organisations have begun exploring alternative approaches to evaluate, communicate and justify the investment in climate resilience (Sivapalan & Cassie, 2022). One approach is to use scenario analysis which is the process of constructing one or multiple future scenarios to model a climate-driven event occurring. The approach considers 'what if' an event was to occur and 'what might' the consequences look like. This method can be used to connect an audience with the impact and scale of the event and then work towards the question of 'so what can we do about it?'. Subsequently, this leads to an assessment of resilience, considering climate adaptation measures that could avoid the impacts of the event. The approach has utility when considering specific scenarios and adaptation options but is less useful the greater number of scenarios and options that are assessed.

Another approach is to use probabilistic modelling through Monte Carlo simulation. This method relies on providing a range of values for each input variable to analyse the sensitivity of a specific variable and the scale of uncertainty. This approach highlights the correlation between the input variables and the variance in the results, including which specific variables create the largest variance. The Monte Carlo analysis can run several simulations (i.e., 10,000) to present a probabilistic interpretation of the outcomes. This method is valuable for decision-makers to understand the distribution of possible outcomes but is highly reliant on the assumptions that underpin the model and the parameters, including the range and distribution of value within each variable.

3 DYNAMIC DECISION TOOLS

The uncertainty and complexity of climate-related risk events lends itself to a combination of these approaches. To support this multi-method approach, organisations would benefit from the use of dynamic decision tools to aid the decision-making process. Dynamic decision tools assist decision-makers to connect with the problem, improve knowledge of options, help clarify what matters most, and understand the implications of each option in a more simple and visual way. Dynamic decision tools can also test the sensitivity of variables in a live environment to demonstrate the correlation between the range of single or multiple variables and the performance of options.

We recently worked with a major Australian water utility to evaluate climate resilient investment options to prepare for a flood event using a dynamic decision tool. The ability to tell a clear story, supported by the tool, enabled the organisation's executive team to assess the merit of climate resilient options to inform decision-making.

3.1 FEATURES OF THE DYNAMIC DECISION TOOL

The dynamic decision tool was built based on the information, datasets, and context of the decision provided by the project team and guided by the questions from the executive team. The tool can be accessed by participants and stakeholders in a decision process through a web-based interactive platform to understand, communicate, and analyse information through multiple methods including scenario analysis, NPV, benefit/cost breakdown, cashflow, and sensitivity (including Monte Carlo analysis). The dynamic decision tool presents a visualisation pane and variable sliders, as presented in the case study in Figure 1. The variable sliders can be toggled left and right to test the sensitivity between the high and low range of the variable and the correlation with options.

4 CASE STUDY | FLOOD RESILIENCE OPTIONS

A water treatment plant, responsible for producing 1,000 megalitres of drinking water per day, is situated in a region impacted by multiple flood events over the past decade. These events triggered the organisation to conduct an asset and operational risk assessment which found a high risk of inundation that could lead to the failure of critical electrical infrastructure. A loss of electrical supply would stifle water supply from the plant, with the estimated loss quantified at 1/3 of the organisation's water supply capability for up to 6 months. This would result in a significant impact on local communities and surrounding industry. To address this challenge, the project team developed a suite of possible resilience options of varying scale, cost, and complexity. The options and CAPEX estimates are included below (Table 1).

Table 1: Flood resilience options and associated costs

Option No.	Option Name	CAPEX
-	Base Case	-
1	Levee	~$15M
2	Elevate Switch room (ES)	~$35M
3	Levee + Raw Water Pump Station	~$45M
4	ES + Submersible Pumps	~$50M

The outcomes were initially communicated to the executive team via static Excel model outputs including a deterministic BCR for each option along with supporting technical information. Although this information was valuable, the executive team were unable to make an informed decision due to uncertainty in the model and lack of transparency of underlying assumptions which could not be resolved at the time of the discussion.

To support the executive team, make an informed decision, we developed the dynamic decision tool building on the framework in the static Excel model. We broadened the scope of benefits and constructed multiple event scenarios to model the impacts of one or multiple floods of different scales over a 30-year time period. (Figure 1.)

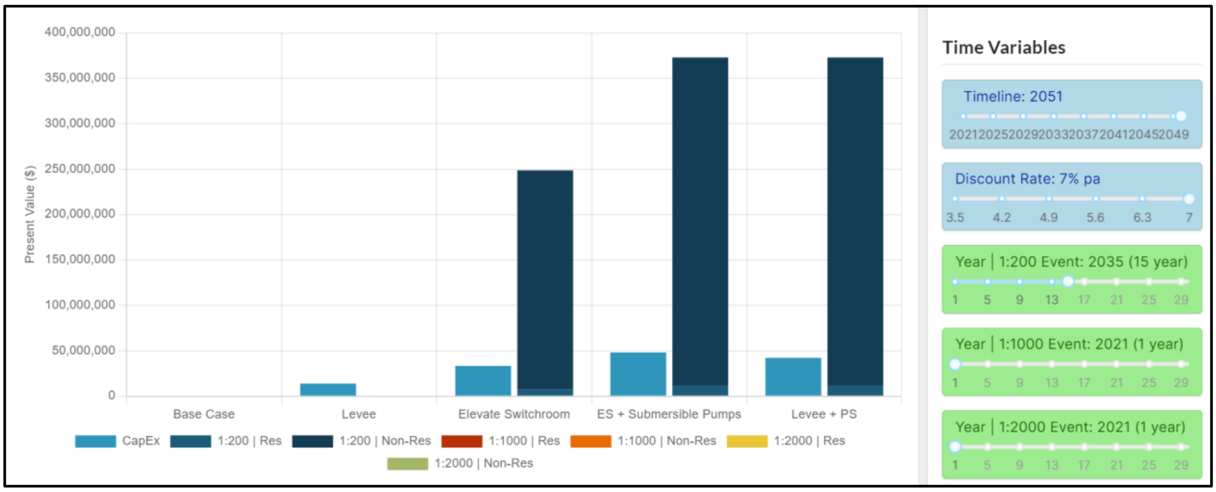

Figure 1: Cost and benefit values presented in the dynamic decision tool with variable sliders on the righthand panel.

We assigned a low, medium, and high value for each of the relevant underpinning variables in consultation with the project team; referencing industry available data to test the sensitivities of variables to the performance of options through Monte Carlo analysis. (Figure 2.)

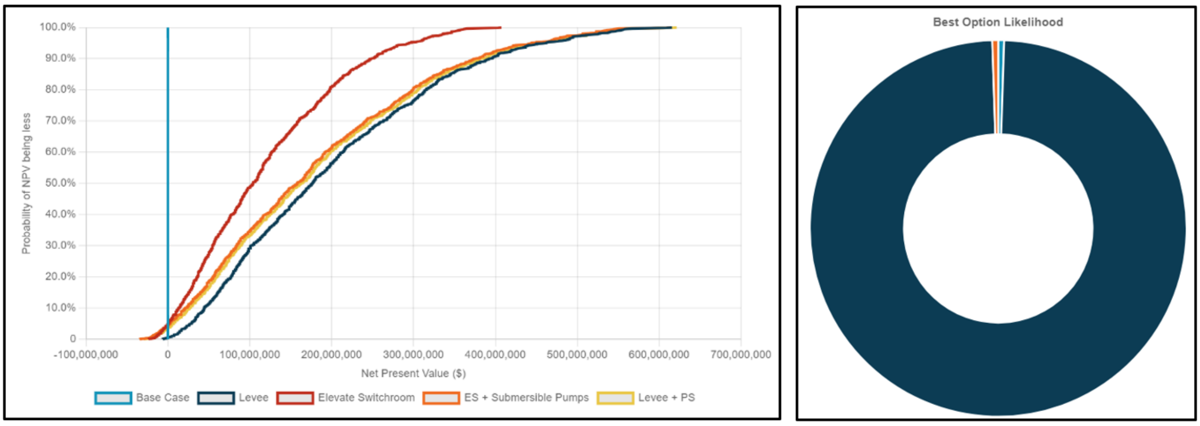

Figure 2: Monte Carlo analysis presented in the dynamic decision tool with probabilistic NPV curves on the left pane and the best option likelihood on the right pane.

The initial area of uncertainty dynamically modelled was the range and scale of flood event scenarios and associated frequencies within the 30-year time horizon. We created three scenarios 1:200-year, 1:1000-year and 1:2000-year events. The frequency of each event was escalated over time to account for future climate projections by approximately a factor of 2, representing another dimension of uncertainty. For example, a 1:200-year flood event would become a 1:100-year flood event over the time-horizon. The impacts of each flood event were established based on a range of economic values attributed to the loss of water supply duration and implications to customers.

The uncertainty in the estimated benefits was dynamically modelled to include the selection and variance in the valuation of benefits into the future. The original benefits assessment was calculated by avoiding the impacts on residential customers. An economic value was associated with the number of customers impacted, the duration of impact, and the scale of water supply loss. The scope of benefits was then broadened to consider the inclusion of non-residential customers; those that used the supplied water for commercial, recreational, or other purposes. In addition, a high, medium, and low range of economic multipliers, discount rates, and demand growth rates were included to reflect additional parameters of uncertainty in the benefits valuation over time.

The cost uncertainty was dynamically modelled to provide transparency on the underlying assumptions of the cost associated with capital projects (CAPEX). We consulted the project team and available industry data to estimate a low, medium, and high CAPEX for each of the options. The uncertainty in project CAPEX is particularly relevant in today's market conditions, noting the current hyper-escalation of costs for labour and materials for construction activities.

4.1 SCENARIO ANALYSIS

The aspects of uncertainty that influenced the decision were the scale of the flood event and the consideration of non-residential benefits. The first three scenarios presented in sections 4.1.1, 4.1.2 and 4.1.3 do not include the economic benefits to non-residential customers. Section 4.1.4 includes the addition of non-residential customers to the 1:200-year flood event scenario.

4.1.1 WORST-CASE SCENARIO

In a climate scenario where multiple flood events, including a 1:2000-year event, occurs, the organisation was subject to a more than $1 billion risk exposure if they opted for no additional flood resilience measures as shown in Figure 3. Each of the four options reduced the risk exposure by between 50% - 99%, not including their respective CAPEX. However, the broader implications of this scenario to the community would be far greater than just the immediate loss of water supply.

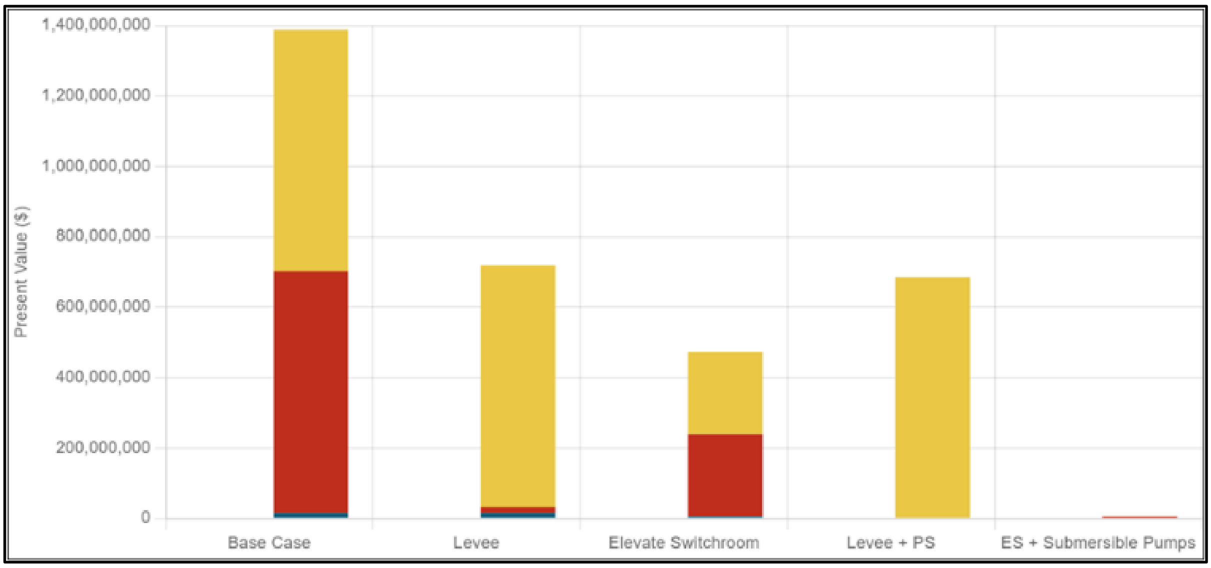

Figure 3: Residual risk exposure to the worst-case scenario, CAPEX excluded, non-residential benefits excluded.

4.1.2 1:1000-YEAR FLOOD EVENT SCENARIO

A risk exposure of approximately $680 million was estimated for a 1:1000-year flood event, which still carried a significant risk exposure to the organisation, as depicted in Figure 4. Both levee options and the elevated switch room with submersible pumps significantly reduced the risk by over 98%.

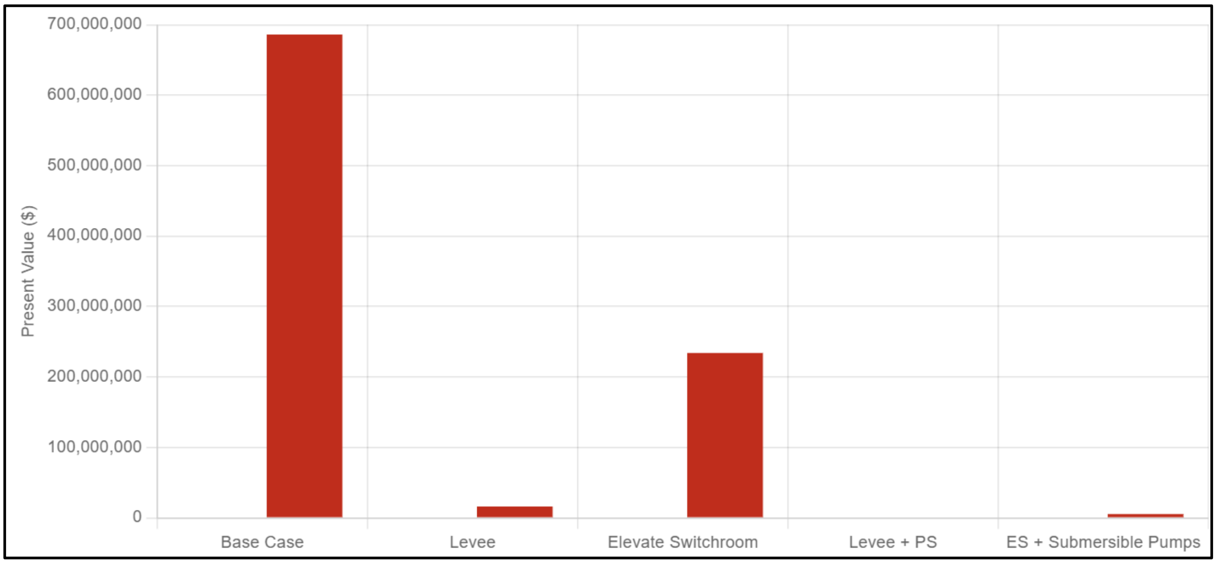

Figure 4: Residual risk exposure to a 1:1000-year flood event scenario, CAPEX excluded, non-residential benefits excluded.

When considering the CAPEX of each option, investing in the levee (approximately $15 million, generated the greatest value when trading off cost and risk. (Figure 5.)

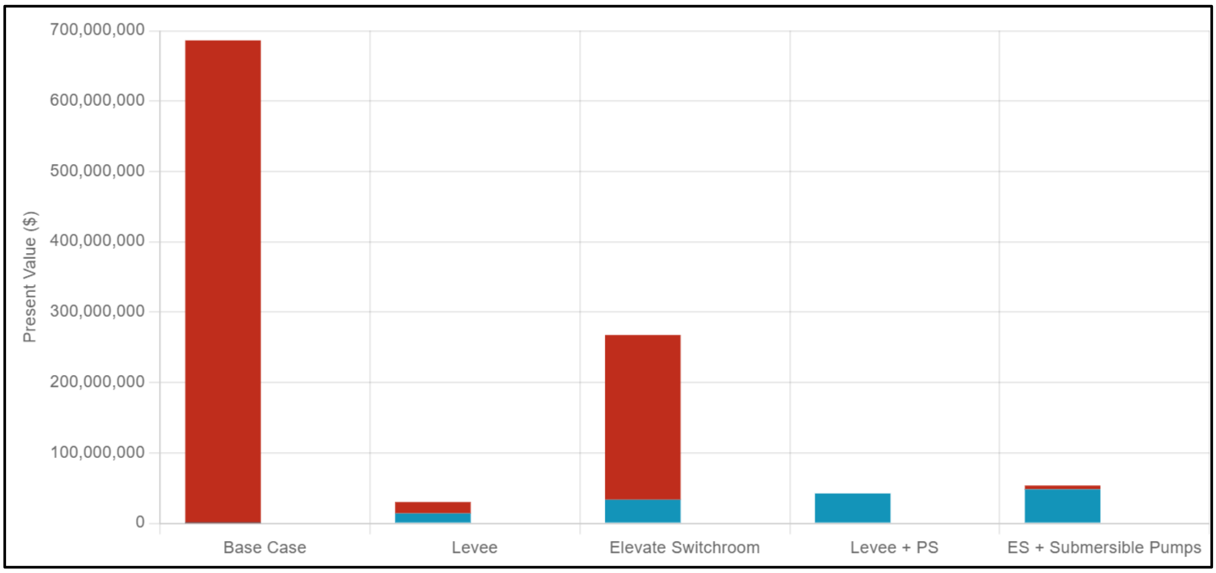

Figure 5: Residual risk exposure to a 1:200-year flood event scenario, CAPEX included, non-residential benefits excluded.

4.1.3 1:200-YEAR FLOOD EVENT SCENARIO

A risk exposure of approximately $16 million (±50%) was estimated for a 1:200-year flood event, which is significantly less compared to the worst-case scenario. Investing in any of the options to prepare for an event of this nature would not provide an economic return, based on the medium values for input parameters. (Figure 6.)

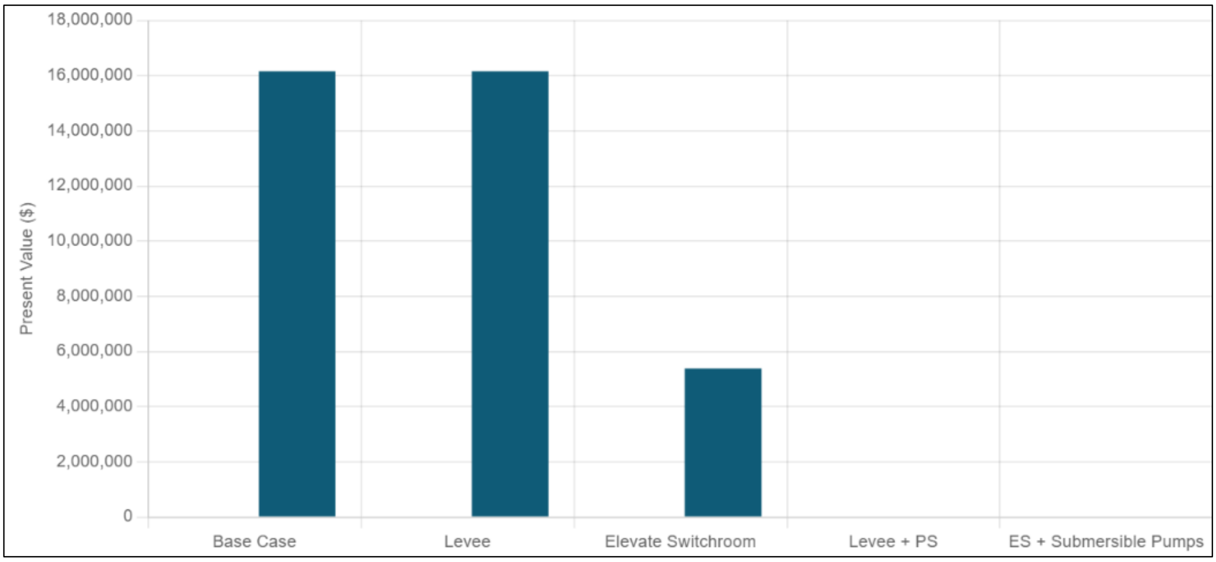

Figure 6: Residual risk exposure of each option to a 1:200-year flood event, CAPEX excluded, non-residential benefits excluded.

4.1.4 1:200-YEAR FLOOD EVENT SCENARIO, INCLUDIING NON-RESIDENTIAL BENEFITS

The economic value of the benefits significantly increased when the non-residential customer benefits were considered. The non-residential benefits were substantially greater than the residential benefits, represented through a risk exposure of approximately $500 million (±100%). Therefore, the more expensive capital solutions would significantly mitigate the risk exposure. (Figure 7.)

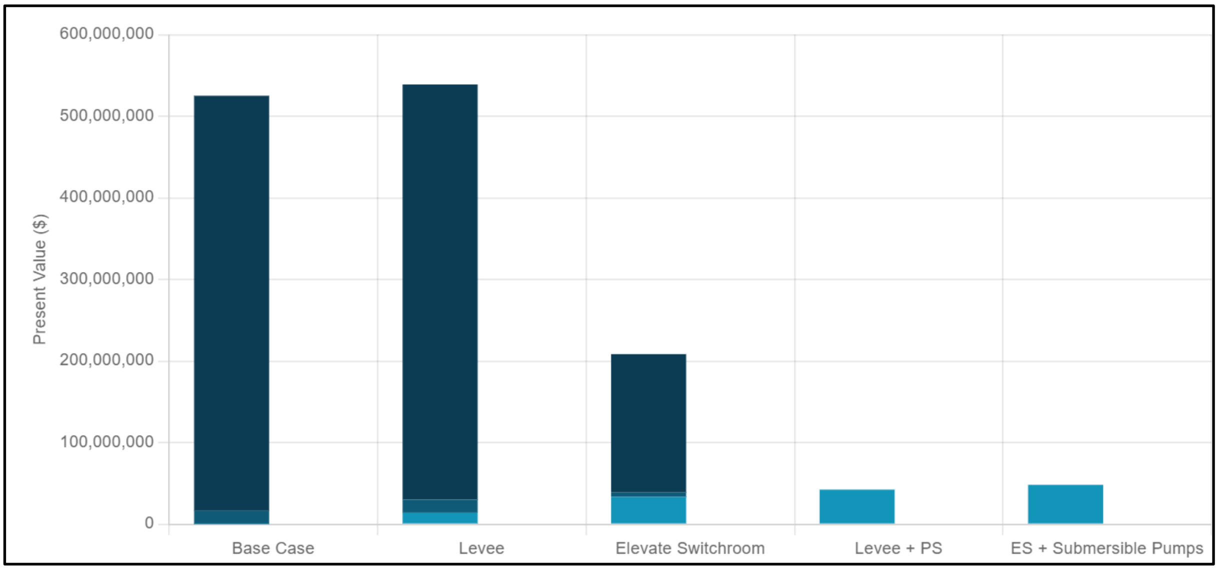

Figure 7: Residual risk exposure of each option to a 1:200-year flood event, CAPEX included, non-residential benefits included.

4.2 MONTE CARLO ANALYSIS

To consider the probabilistic outcomes, a Monte Carlo analysis was performed across the flood scenarios to understand the relative performance of options, and within each option, across the range of uncertainty in the variables.

Table 2 shows the results of the Monte Carlo analysis across the three individual flood scenarios and a multiple flood scenario, excluding and including non-residential benefits.

Table 2: Outcomes of the Monte Carlo analysis for each flood event scenario.

Flood event scenarios	Best Performing Option	Comments
Excluding non-residential benefits		
1:200-year	Base Case	The capital costs of all four options are greater than the flood resilience benefits.
1:1000-year	(1) Levee	Both levee options are more favourable than the base case and other options. The cost increase to add the raw water pump station does not provide greater proportion of benefits.
1:2000-year	(4) ES + Submersible Pumps	For a worst-case scenario flood event, the elevated switch room with submissible pumps provides greater resilience value.
Multiple flood events between 1:200 and 1:1000 year	(1) Levee	Both levee options are more favourable than the other options. The cost increase to add the raw water pump station does not provide greater proportion of benefits, even in response to multiple flood impacts of this scale.
Including non-residential benefits		
1:200-year	(3) Levee + Raw Water Pump Station	The levee in combination with the raw water pump station provides the most value closely followed by the elevated switch room option.
1:1000-year	(3) Levee + Raw Water Pump Station	The levee in combination with the raw water pump station provides the most value closely followed by the elevated switch room with the installation of submissible pumps.
1:2000-year	(4) ES + Submersible Pumps	For a worst-case scenario flood event, the elevated switch room with the installation of submissible pumps provides the greater resilience value.
Multiple flood events between 1:200 and 1:1000 year	(3) Levee + Raw Water Pump Station	The levee in combination with the raw water pump station provides the most value closely followed by the elevated switch room with the installation of submissible pumps, even in response to multiple flood impacts.

4.3 IMPLICATIONS FOR DECISION MAKERS

The risk exposure to the organisation was significant due to the criticality of the electrical infrastructure and the potential impacts on the continuity of supply. For the worst-case scenario modelled, the economic impacts were estimated at over $1 billion. In this scenario, the likely scale of impacts across the region would be catastrophic and the continuity of water supply would be one of many challenges for the region. It was agreed to exclude this scenario from the scope due to the catastrophic nature.

For a 1:1000-year event the risk exposure to the organisation based on economic impact to residential customers is calculated to be approximately $680 million. An event of this nature is more likely than the worst-case scenario and can be considered a realistic upper limit for the assessment boundary. A 1:200-year event carried a significantly reduced impact, costing approximately $16 million per event, and is considered a realistic lower boundary to achieve a minimum level of resilience. It is worth noting that an event of this nature may become a 1:100-year event within the evaluated time-horizon.

When considering the impact to non-residential customers in the scope of the assessment, the consequences of an event were substantially greater, and therefore the case for investing in resilience was stronger. The justification of investing in more capital-intensive options was sensitive to the inclusion of non-residential benefits, directly correlating with the viability of the outcome. A further study was recommended to qualify the inclusion of non-residential customer benefits. If non-residential customer benefits are to be included, a more detailed economic evaluation should follow to improve the accuracy.

Based on available information, and subject to the non-residential benefits review, it was recommended to construct the levee to provide the most economically viable investment in resilience for up to a 1:1000-year flood event. In addition, there was the ability to add the raw water pump station once there was further clarification on the inclusion and value of non-residential benefits.

The use of the dynamic decision tool allowed the executive team to gain greater clarity regarding the trade-offs between cost, risk exposure, and the long-term benefits in a live environment to inform their decision.

CONCLUSIONS

Our world is becoming increasingly vulnerable to natural disasters and extreme weather events driven by climate change. The need to build resilience to climate events of this nature is essential for the continuity of service to communities and protection of critical infrastructure for asset-intensive organisations. The typical CBA method to assess climate resilient options can misrepresent the value of resilience based on how benefits are calculated for low likelihood, high consequence events. In addition, the dynamic nature of these events, and lack of transparency in the assumptions used, lessens confidence in a deterministic CBA assessment and in the decision-making process.

Scenario analysis and sensitivity analysis, through Monte Carlo simulation, are two emerging methods to evaluate climate resilient investments. Both methods serve specific purposes and in combination with a CBA framework, they can support decision-makers connect with the problem, improve knowledge of options, help clarify what matters most, and understand the implications of each option.

Organisations would benefit from a dynamic decision tool that can support effective communication and analysis to understand the consequence of climate driven-risk events and the value of resilient options. These tools allow for the integration of multiple assessment methods including scenario analysis and dynamic sensitivity to test the correlation of variables with the performance of options. Through this analysis, decision-makers can understand the trade-offs between cost, risk exposure, and the long-term benefits when considering investments in climate resilience. This form of will position asset-intensive organisations to adapt to climate change-driven risks based on informed decision-making.

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